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I.O.L.R. REPORTS

PN-ABT-367

ECOLOGICAL ASSESSMENT OF THE GULF OF NICOYA - COSTA RICA

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ECOLOGICAL ASSESSMENT OF THE GULF OF NICOYA - COSTA RICA

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ECOLOGICAL ASSESSMENT OF THE GULF OF NICOYA - COSTA RICA

A. Activities performed during the first year of the project

1. Planning Meeting

The initial planning meeting took place in Heredia, Costa Rica during 8-12 November 1993, with the participation of Sandra Leon Cotto, Carlos Brenes, Guillermo Quiroz and Joaquin Chaves from the Universidad Nacional, Heredia, Costa Rica and Steven Brenner and Nurit Kress from the Israel Oceanographic and Limnological Res. Israel. The purpose of this meeting was to discuss and finalize the details of the experimental set-up, cruise planning, equipment purchase, data analysis and training relevant to the project as well as to start the preparation of a manual of the methods to be used during this research.

The working week in Costa Rica started with a visit to the facilities of the Department of Chemistry and the Oceanography computer laboratory. Initialy we discussed the 30% budget cut by AID-CDR and how the plans could be changed in order to accommodate the budget cut as well as to achieve all of the aims stated in the proposal. Carlos Brenes and Sandra Leon mentioned that they have data from a series of 12 monthly cruises conducted in the Gulf of Nicoya from April 1992 to March 1993 and that this data could be used in the project. Therefore, the number of cruises could be decreased, reducing shiptime costs and moreover, laboratory analysis and data processing costs. They presented the results of the twelve cruises during which 20 hydrographic stations were sampled and the following parameters measured: temperature, salinity, dissolved oxygen and nutrients (o-phosphate, nitrate, nitrite and silicic acid). The coverage of the hydrography of the gulf was extensive and it was possible to determine the seasonal and spatial dependence of the parameters. Section A-2 below shows a preliminary analysis of the existing data, relevant to the project. These data are sufficient to calibrate the model and are even better than the proposed sampling scheme of five cruises per year, because they provide a more complete time series.

In order to adapt and run the model for the Gulf the following information is needed: 1. temperature and salinity distribution in the Gulf 2. bathymetry of the Gulf 3. shore line contour 4. historical data on temperature, salinity and circulation outside the gulf, on the continental shelf (to set up the boundary conditions) 5. tidal components 6. river inputs (quantity of water discharge) 7. meteorological data (winds, relative humidity, temperature) 8. if available, previous measurements of currents in the Gulf..

Some of the data needed are either scarce (like currents) or non existent (like winds and meteorology). The model will be run under assumptions (or best guess) of the missing parameters. If it turns out that the model predictions differ from the observations, an effort will be made to measure the missing information (i.e. if wind and not thermohaline forcing is the main driving force controlling circulation, then data on winds will be collected. Note: winds are very complex in the Gulf and the patterns can be completely different in the inner and outer part. Based on the topography of the region we expect the predominant winds to be either from the NW or SE). Costa Rica will gather the data and send it to Israel. The adaptation of the physical model to describe the circulation in the gulf as well as the graphics output will be performed jointly by Costa Rica and Israel using electronic mail.

We then split into two working groups. Steve and Guillermo worked in the Oceanography Computer lab and successfully installed the model in the computer as well as run it for a simple case study of a wind driven ocean basin. They also worked on setting up electronic communication between the two institutes.

Sandra, Carlos, Joaquin and Nurit went over the technical work plan (Section C of the original proposal , page 11) and revised the proposal. It should be emphasized that the aims of the project remain the same as stated in the original proposal. The main changes were made in the plans for the field work.

Revision of the sampling scheme and methods to be used in the project

Water samples, hydrography and sediments

Even though there is already an extensive hydrographical data base collected during 1992-1993 that permits the model to be run, it was decided to perform two additional hydrographic cruises: one during the dry season (April 94) and the other during the rainy season (October 94) in order to have synoptic data of the hydrographic parameters with chlorophyll-a and heavy metals in sediments and fauna. These latter parameters were not measured previously. 20 hydrographic stations will be occupied at which profiles of temperature, salinity, dissolved oxygen, nutrients (o-phosphate, nitrate, nitrite and silicic acid) and chlorophyll - a will be measured. During these two cruises, sediments will also be sampled at the hydrographic stations and at three additional stations: one close to the Tempisque, one close to the Barrancas and one close to the Tarcoles river mouths.

Fish and benthic fauna

Fish and benthic fauna will be collected twice per year, for two years: once during the rainy season and once during the dry season. Three different areas will be sampled: the upper gulf, the Puntarenas-Tercoles region and a control area in the outer gulf, at the south-west bank. We discussed the three species to be analyzed: a crustacean from the Penaeus sp.,the mollusk Anadara tuberculosa and a fish species. The most abundant fish in the gulf is the corvina but since there are 24 corvina species in the Gulf it is very difficult to differentiate between them. Therefore, Sandra and Joaquin will consult a fish ecologist and choose a species that is representative of the Gulf, can be found in the three areas and is non migratory. Between 10-15 specimens of each species will be analyzed during each sampling .

Sample treatment and analysis

Water samples

Dissolved oxygen will be measured by an oxymeter (Yellow springs company, Colorado) calibrated against Winkler titration. Samples taken from below 50m depth will be fixed on board and determined by Winkler titration in the lab. The oxymeter has a sensor for temperature measurement but salinity will be measured in the lab by a salinometer. Chlorophyll-a will be determined by the spectrophotometric method described in Strickland and Parsons and in the UNESCO manual. Nutrients will be measured by the manual methods described in Strickland and Parsons with some modifications introduced by the Costa Rican laboratory, mainly the reduction of sample volume.These determinations will be performed by the group from Costa Rica.

Sediments

Heavy metals in the sediments will be determined by the methods stated in the proposal. The only modifications are: sediments will be dried by lyophylization, granulometric analysis will be performed by settling time instead of wet sieving, due to the large proportion of the small size particle (60-80% of the total sample), and organic carbon will be determined by the dichromate method. These analyses will be performed both by Costa Rica and Israel. Nurit is taking three sediment samples of the upper Gulf region to perform a preliminary analysis of the heavy metal contents in the area.

If the sediments are sampled by corer we will decide before the cruise on the depth of the layer to be analyzed. For pollution work, the thinner and closer to the surface, the better (and more representative of the actual pollution situation). But the depth of the layer will be decided based on the amount of sediment needed for analysis.

Concerning the determination of organic compounds in the sediments by GGC (USA) it was decided not to analyze for volatile organics due to the high cost of analysis and shipping. Therefore, only non volatile organics will be determined allowing for more samples to be analyzed and consequently for a better description of the spatial distribution of the organic contaminants.

Field trip to the Gulf of Nicoya and surrounding area

In addition to the discussions concerning the project we went on a field trip to the Gulf of Nicoya and surrounding area , including the Arenal-Tempisque Irrigation Project.

The trip started in Heredia, with the first stop in Esparza. After that we arrived in Canas, where an official from SENARA toured with us and explained the irrigation project that canalizes water from the Arenal hydroelectric project to rice and sugar cane plantations. The residual water (ca. 25%) rejoins the Tempisque river and enters the gulf. This project may be an important source of contaminants (fertilizers, herbicides, insecticides and fungicides) to the waters of the Gulf of Nicoya. The waters of the irrigation project also feed a fish farm that grows telapia for export.

The next stop was the mouth of the Tempisque river (at the ferry station) with a view to the Gulf. Puntarenas was reached by two o'clock. We toured the various sites of the city: the estero where most of the wastes from the city enters the gulf, the fishermen dock and the tuna canneries. We were shown the unusual geographical setting of Puntarenas . The last stop of the trip was the Caldera port.

2. Summary of existing data

As noted above, the gulf was sampled 12 times between April 1992 and March 1993. Water samples were collected at standard depths (0, 5, 10, 20, 30, 40, 75 and 100m) using Niskin bottles. Salinity was determined by an inductive salinometer and temperature and dissolved oxygen by a portable oxymeter. Samples for the determination of nutrients (nitrate, nitrite, silicic acid and o-phosphate) were sampled into 500 ml polyethylene bottles and immediately frozen. The samples were analyzed in triplicate by the photometric methods described by Strickland and Parsons (1972) at the Marine Chemistry Laboratory at the Universidad Nacional. The geographical distribution of the sampling stations (Fig.1) was chosen in order to determine the influence of the three main rivers (Tempisque, Barranca and Tarcoles), the coastal waters and the bathymetry and topography of the Gulf on its hydrography.

<u>Seasonal variation along the central transect of the Gulf.</u>

The annual march of surface temperature along the central axis of the Gulf (measured as distance from the mouth of the Tempisque river) is shown in Figure 2a. Both the annual and spatial variations are quite small with typical values of one degree or less. Along the axis, throughout most of the year, the coolest water appears midway down the Gulf (about 50-60 km from the Tempisque). In the central and southern parts of the Gulf (more than 40 km from the Tempisque) the dominant mode in the annual march of temperature is the first harmonic with maximum values occurring some time between May and July and minimum values in January-February. The northern part of the Gulf is the warmest region with the annual cycle characterized by two maxima (one in June and one in December) separated by a weak minimum in September. The minimum is probably due to the cumulative discharge of cooler water from the Tempisque during the rainy season. The distribution of temperature at 5 m depth is very similar to the surface pattern as shown in Figure 2b.

The surface salinity field (Figure 3a) shows very strong spatial and temporal gradients in the extreme upper Gulf (within 10 km from the Tempisque). The annual march of salinity occur in August-September corresponding to the temperature minimum discussed above. This is clearly related to the fresh water input from the Tempisque as August-September is already in the latter part of the rainy season. Beyond 30 km from the Tempisque, the surface salinity is fairly uniform along the axis as well as in time, although we can see a weak signal associated with the time lag in the progression of the fresh tongue along the axis. The distribution of salinity at 5m depth is very similar to the surface pattern as shown in Figure 3b.

The seasonal variation of surficial oxygen is the opposite of salinity and temperature. Maximal values are found during the rainy season (September and October) when the water is less saline and therefore more oxygen can be dissolved in the water. Low values are found in the dry season, when the waters are more saline (Fig. 4). The influence of the Tarcoles river is reflected by a lens of high oxygen contents, about 75 km from the Tempisque River mouth.

The seasonal variations of nutrients are shown in figures 5 and 6. Nitrate and nitrite levels are usually high during the whole year at the upper part of the Gulf. These levels are constant probably as a result of enough fresh water discharge even at the dry season, generated at the Arenal-Tempisque Irrigation Project. During the rainy season it is possible the see the influence of the Tarcoles river by the nitrate lens (1 µM) located opposite the river mouth, as for the case of dissolved oxygen. O-phosphate and silicic acid behave similarly to nitrate and nitrite in the upper part of the Gulf, with higher values than in the remaining areas. It is possible to see relative higher values at the beginning of the rainy season (May-July) but onl as far as 15 km from the Tempisque river mouth. The seasonal variation of silicic acid is different. High silicic acid concentrations associated with the rainy season (July-November) and increased river discharge spread out to almost 80 km from the Tempisque, showing the influence of the Tempisque as well as the Tarcoles river outflow.

Spatial distribution of surface fields

In order to describe the spatial distribution of the parameters measured in the Gulf at the surface we chose the results of two months, with maximal and minimal values for each parameter. These results represent the two extreme cases while the other samples can be considered as transition conditions between the two extremes.

The spatial distribution of temperature and dissolved oxygen (Fig. 7-8) are similar in both seasons, where the influence of the coastal waters can be detected in the entire lower Gulf. The Negritos Island plays an important role in the distribution of these parameters. It constitutes a physical barrier for the oceanic waters' inflow on the western side of the Gulf as well as for the fresh water plume flowing out on the eastern side. The front that is generated by the convergence of these two water types can be clearly seen by the distribution of surficial salinity (Fig.9), in particular during the rainy season, when the discharge from the Tarcoles river increases considerably.

Nutrient distributions are depicted in Figures 10-13. A general analysis shows, as expected, that the Gulf is devided into two distinct areas concerning nutrient concentrations and therefore productivity. The upper Gulf, from the Tempisque river mouth to the Negritos island, is richer in nutrients and the lower Gulf, from the Negritos island seaward to the adjacent coastal waters, poorer in nutrients. The patterns of the nutrients' distribution are typical for tropical estuaries, where the seasonal cycle and the spatial distribution are determined by the fresh water discharges from the rivers and not by the contribution of the nearby coastal waters via mixing due to the tides.

Stratification

The central transect was chosen to depict the stratification conditions in the rainy and dry seasons. The vertical distribution of temperature (Fig. 14) shows weak stratification during the dry season, when stronger winds and surface cooling induce intense vertical mixing processes. Typical mixed layer depths are 25-30m. During the rainy season (warm) stratification can be seen throughout the water column with typical mixed layer depths of only 5m in the upper Gulf and 10-12m in the lower Gulf.

Vertical distributions of salinity, dissolved oxygen and nutrients (Fig.15-20) are different in the upper and lower part of the Gulf. During the dry season the upper part is well mixed while during the rainy season it is highly stratified, due tot he fresh water input from the Tempisque. During the rainy season it is possible to see also a rising of the isohalines reaching the surface east of the Negritos island (Fig. 15).

3. Preliminary Heavy Metal Determination

Heavy metals were determined in three samples of sediments collected at the upper Gulf, near the Chiva Island (see Fig. 1).

Heavy metals in sediments of the Gulf of Nicoya, Costa Rica 11/2/92.

Sample	Al %	Mn ppm	Cr ppm	Zn ppm	Cu ppm	Pb ppm	Fe %	Cd ppm	Ni ppm
East of Chivas Island (3)	7.43	1206	53.4	77.3	68.7	14.6	4.32	0.17	22.0
North of Chivas Island (5)	7.67	906	45.2	83.6	65.8	14.5	4.47	0.12	22.4
Tempisque river mouth (7)	8.31	1242	43.9	124.3	75.0	15.3	4.84	0.10	19.4

Although we analysed only three samples, it is possible to see that the heavy metal composition is similar to the composition of silty-clay sediments. There is a good correlation between the main constituents measured, Al and Fe. We found low values of Cd and Pb, elements that are indicative of pollution. The sampling program described in A-1 will provide us with a representative sample for the sediments of the whole Gulf.

4. Initial set-up of the hydrodynamic model

The hydrodynamic model selected for use in this project is the Princeton Ocean Model (POM). Briefly, it is a three dimensional, primitive equations numerical model with an embedded higher order turbulence closure scheme. In the vertical it uses a terrain following sigma coordinate in which the water column is scaled by the depth of the bottom so that each grid point contains the same number of levels. This feature makes the model especially well suited to handling problems of coastal and estuarine circulation. The model was installed on the microcomputer in Costa Rica and a simple test case of a wind driven ocean basin was run in order to demonstrate the model's performance and capabilities.

The main effort involved in adapting the model to the Gulf lies in the preparation of the data files needed to : (i) define the model's domain (bathymetry and coastline), (ii) provide initial and calibration condition for the simulations (hydrography and currents if available), and (iii) provide external forcing data (wind stress, surfacc heat fluxes , river discharge and water level at the open seaward boundary). The bathymetry, wind stress, river discharge and tidal component (water level) data have been prepared in ASCII files. After a long delay in establishing electronic communications, Costa Rica finally succeeded in establishing a reliable link to Internet and the necessary data files were than transferred to Israel. This link is crucial for the model development and exchange of information. Preliminary adaptation of the model to the Gulf of Nicoya has been started. As the model development progresses, parallel version of the model and data will be maintained in both Israel and Costa Rica.

5. Equipment Purchase

Costa Rica purchased a Perkin Elmer Atomic Absorption Spectrometer, model 3110. This is the main piece of equipment needed for the implementation of the project. It was installed during October 1994 and is now ready for operation. There were some procedural difficulties in the purchase and therefore it was delayed.

6. Comparison between proposed workplan and actual execution during the first year of the project

a. Meet in Costa Rica to finalize the plans for the project - executed. The meeting took place in Heredia, Costa Rica during 8-12 November 1993, see section A-1.

b. Perform five hydrographic cruises - changed. There is already an extensive data base of hydrographic parameters (13 cruises during one year) that will be used to calibrate the model. Two additional cruises will be performed in 1995, one at the dry season and one at the rainy season in order to sample sediments and biota, in addition to the hydrographic parameters.

c. Purchase of equipment - executed. Costa Rica purchased a Perkin Elmer Atomic Absorption Spectrometer, model 3110. It was installed during October 1994 and is now ready for operation. There were some procedural difficulties in the purchase and therefore it was delayed. Therefore the sampling program was delayed as well.

d. Start data analysis - executed. Hydrographic data were analysed as well as a preliminary determination of heavy metals contents in the sediments of the upper Gulf area.

e. Preliminary hydrodynamics model set-up - executed.

f. Visit of a Costa rican scientist to Israel to study the methods used for heavy metals analysis.- not executed. The visit was postponed to 1995 because of the delay in purchasing the Atomic Absorption Spectrometer.

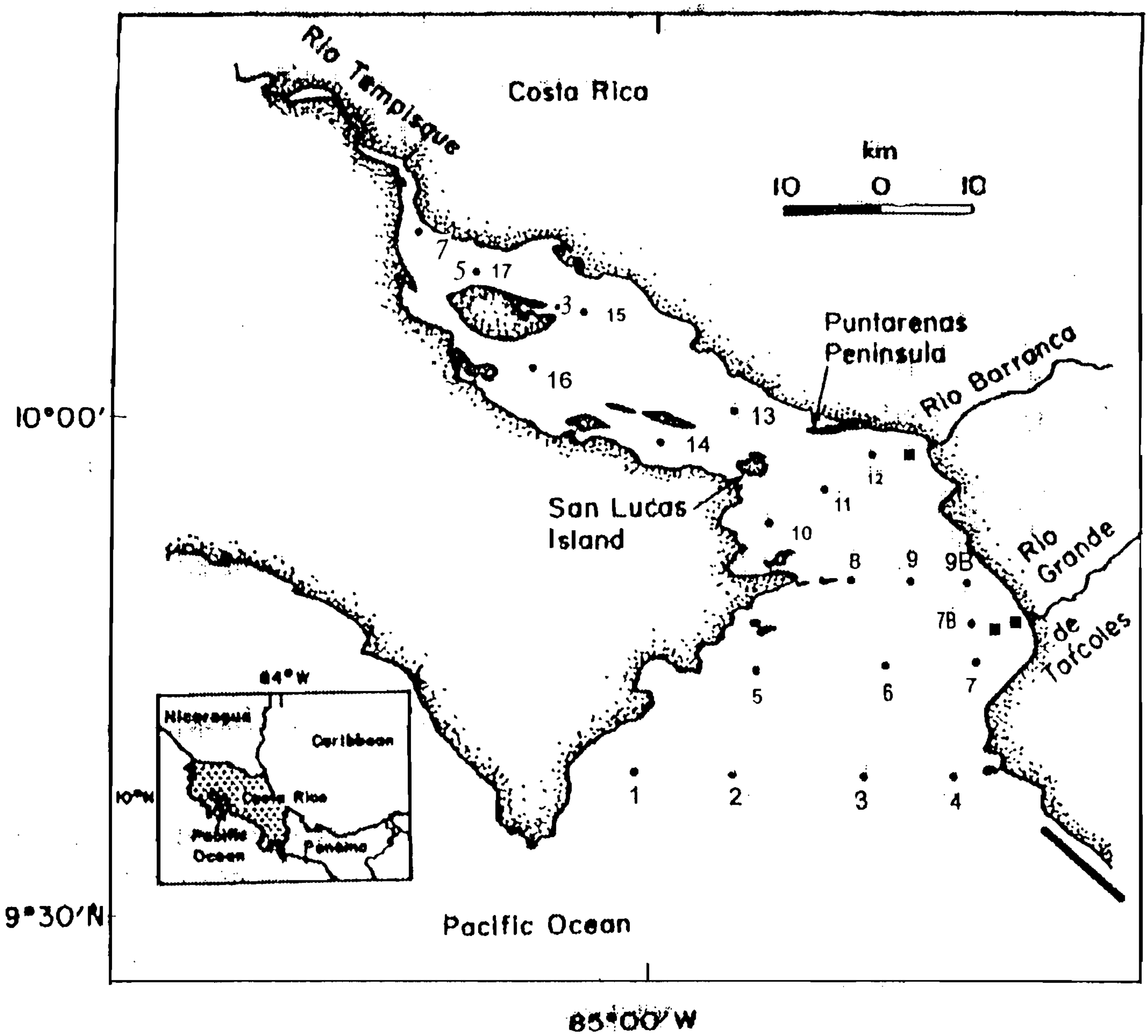


Figure 1. Map of hydrographical sampling stations in the Gulf of Nicoya.
Numbers in italics are the sediments sampling stations.

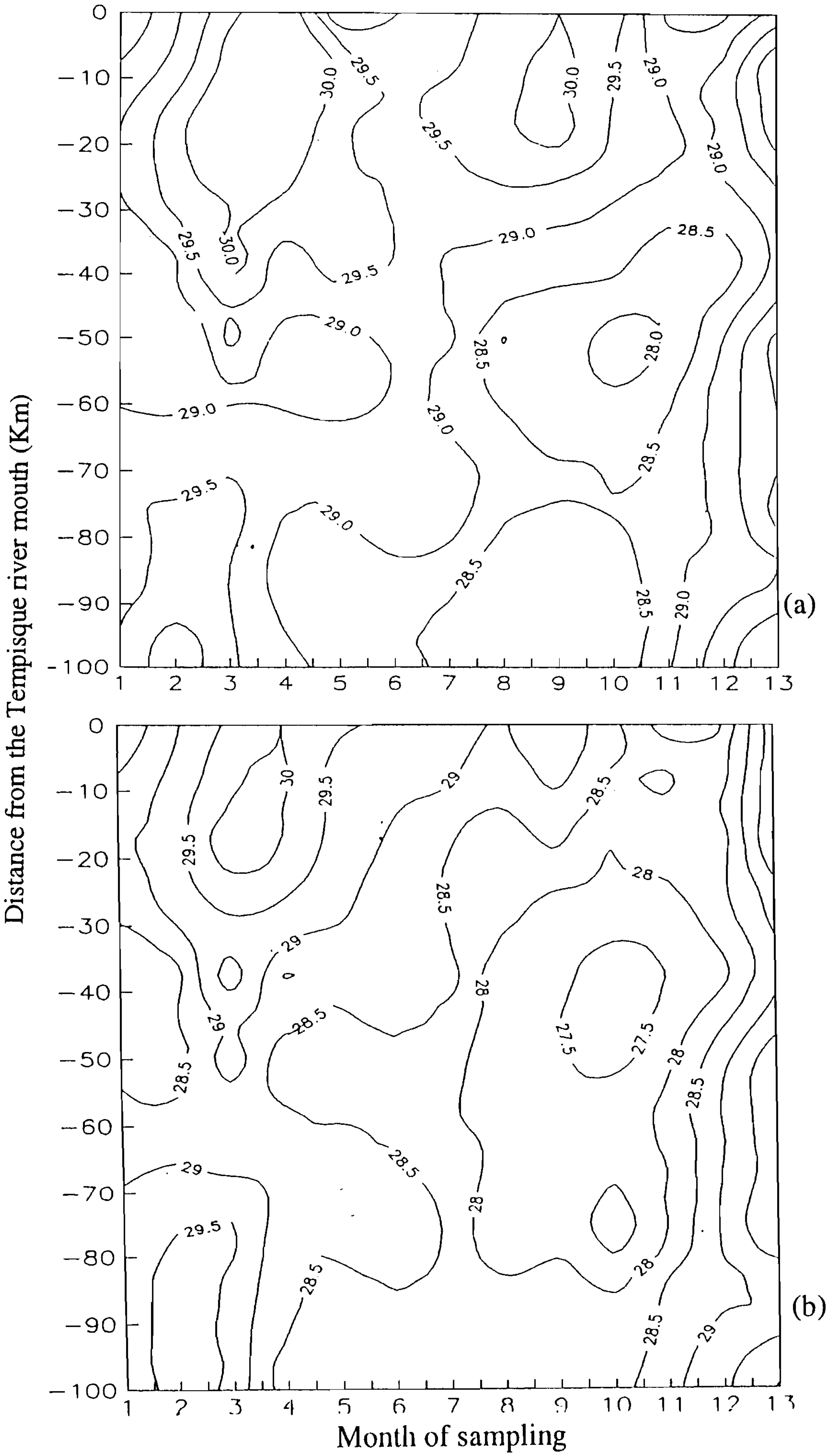


Figure 2. Surface (a) and 5m (b) temperatures (^0C) measured along the central transect of the Gulf asa function of time of the year and distance from the Tempisque river mouth. 1- April 1992, 3- June 1992, 5- August 1992, 7- October 1992, 11- April 1993, 13- May 1993.

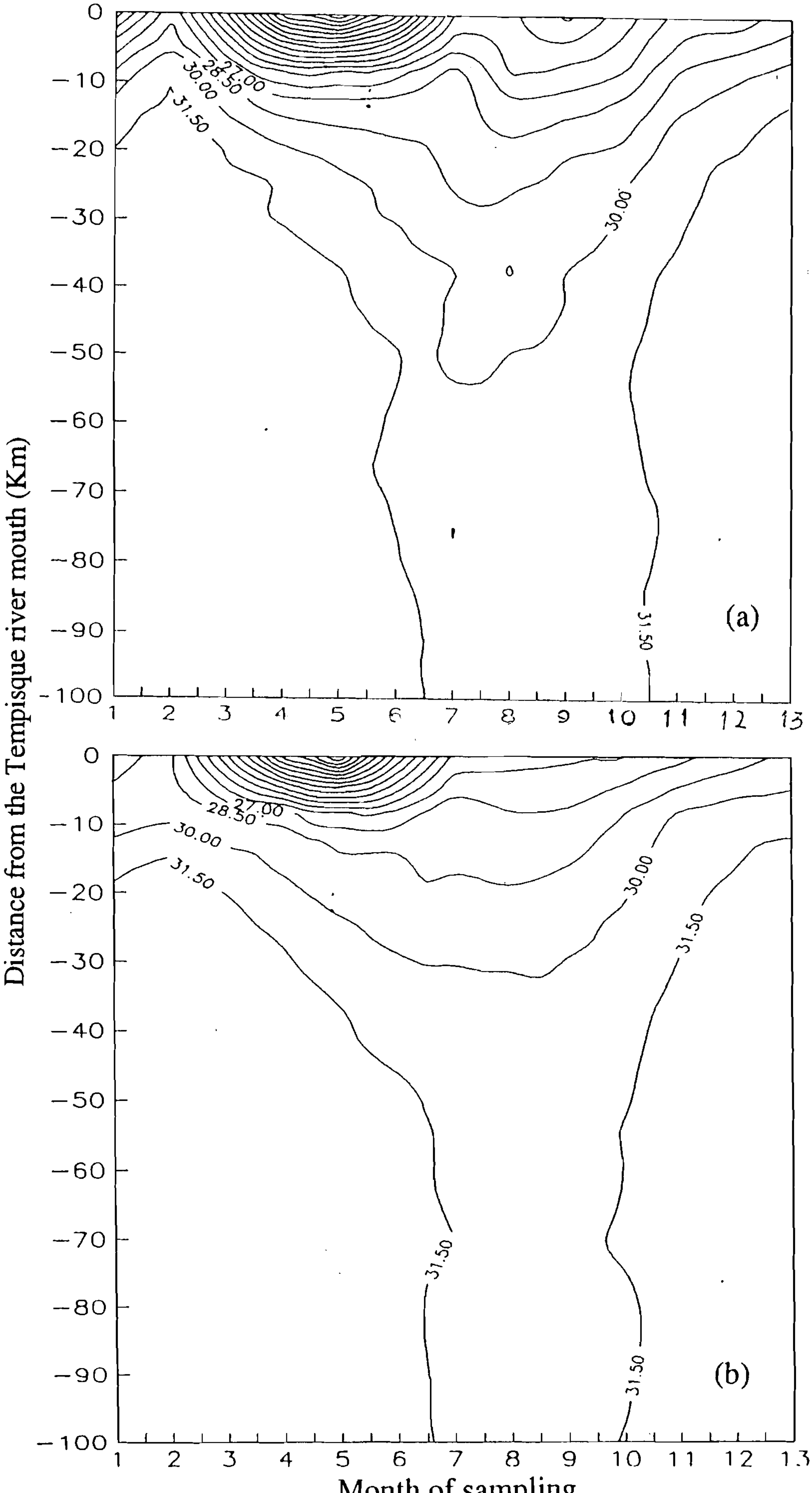


Figure 3. Surface (a) and 5m (b) salinity (ppt) measured along the central transect of the Gulf as function of time of the year and distance from the Tempisque river mouth. 1- April 1992, 3- June 1992, 5- August 1992, 7- October 1992, 11- April 1993, 13- May 1993.

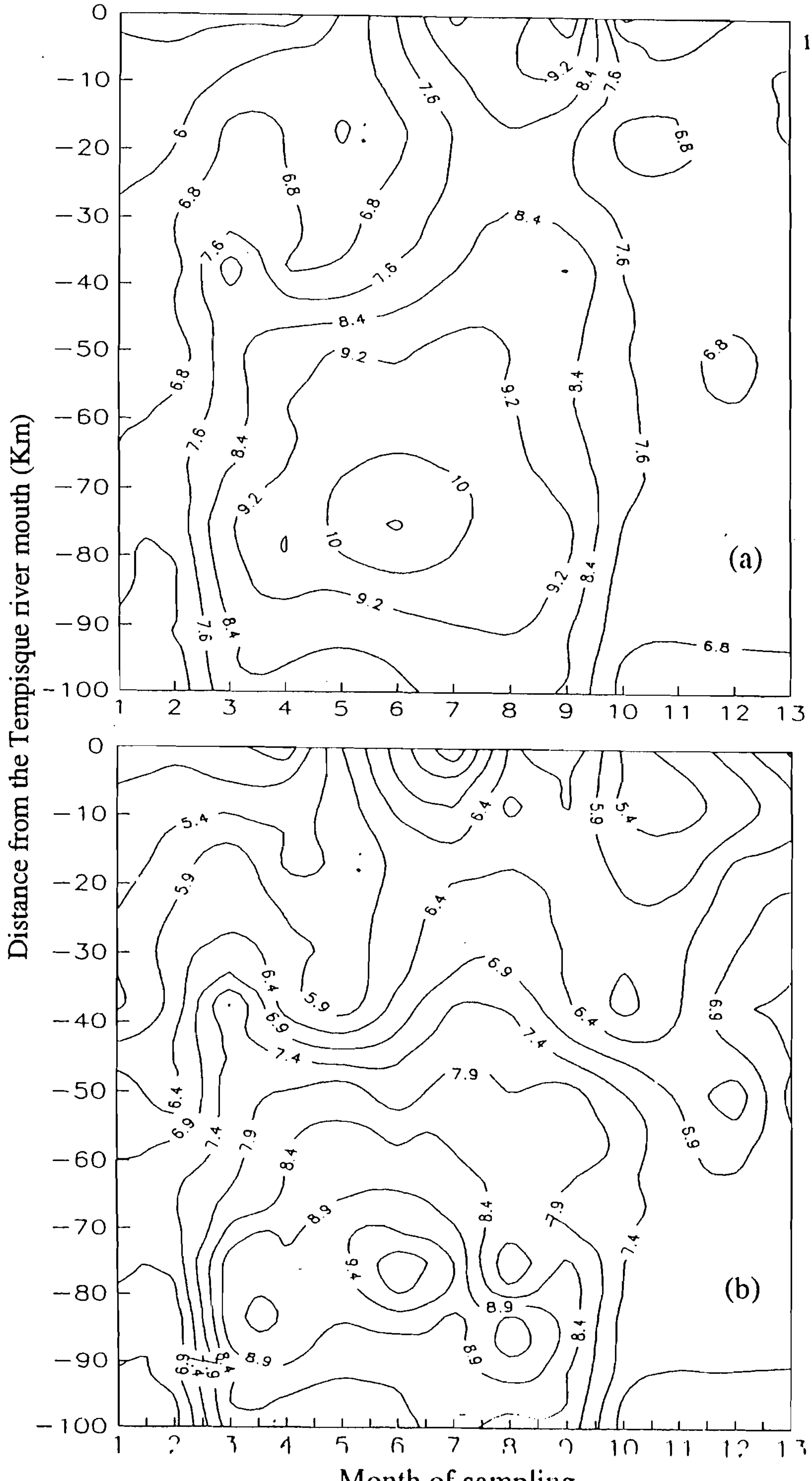


Figure 4. Dissolved oxygen concentration (ml/l) at the surface (a) and 5m (b), measured along the central transect of the Gulf as function of time of the year and distance from the Tempisque river mouth. 1- April 1992, 3- June 1992, 5- August 1992, 7-October 1992, 11- April 1993, 13- May 1993.

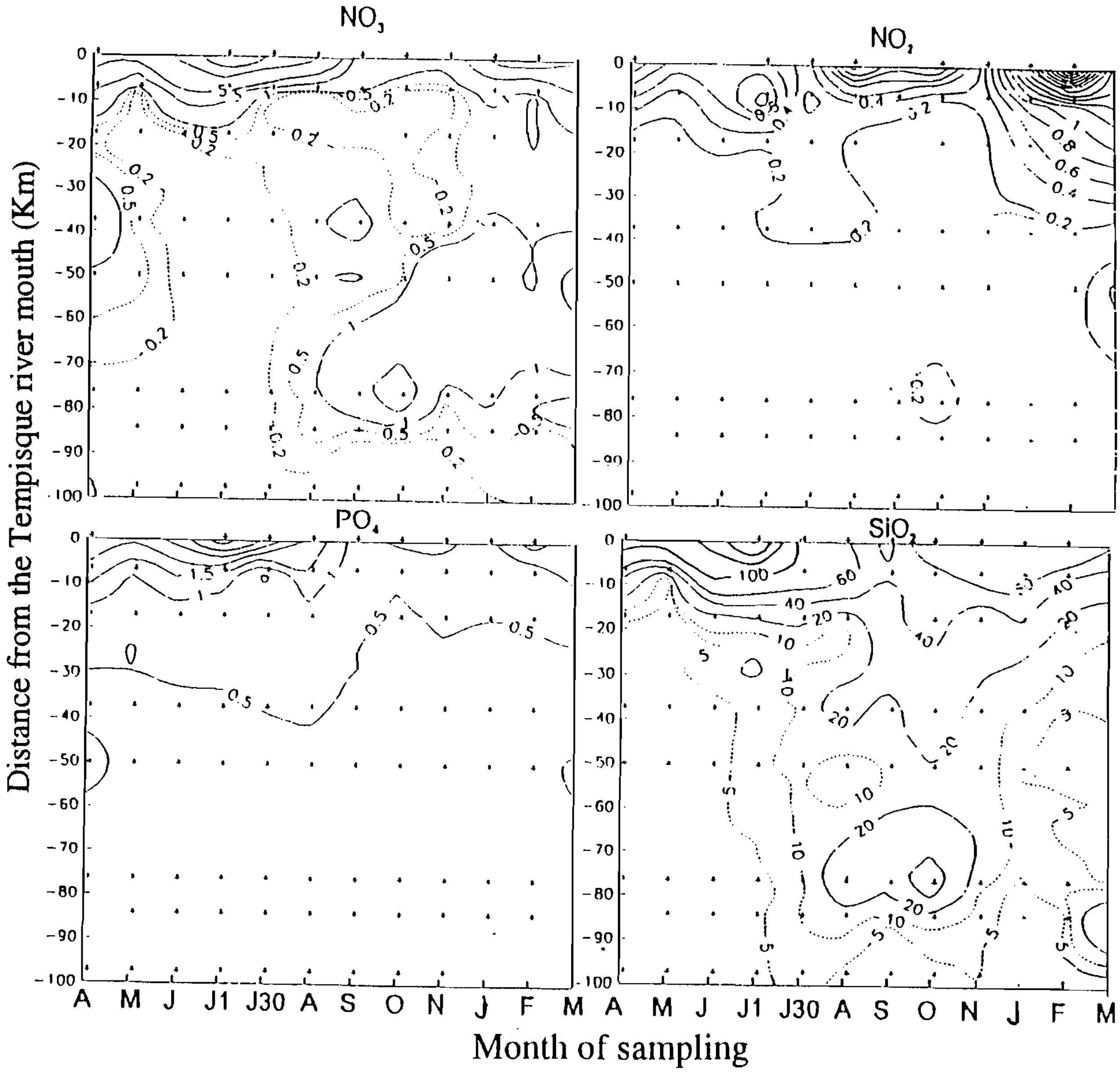


Figure 5. Nutrient concentration (µM) at the surface, measured along the central transect of the Gulf, as function of time of the year and distance from the Tempisque river mouth.

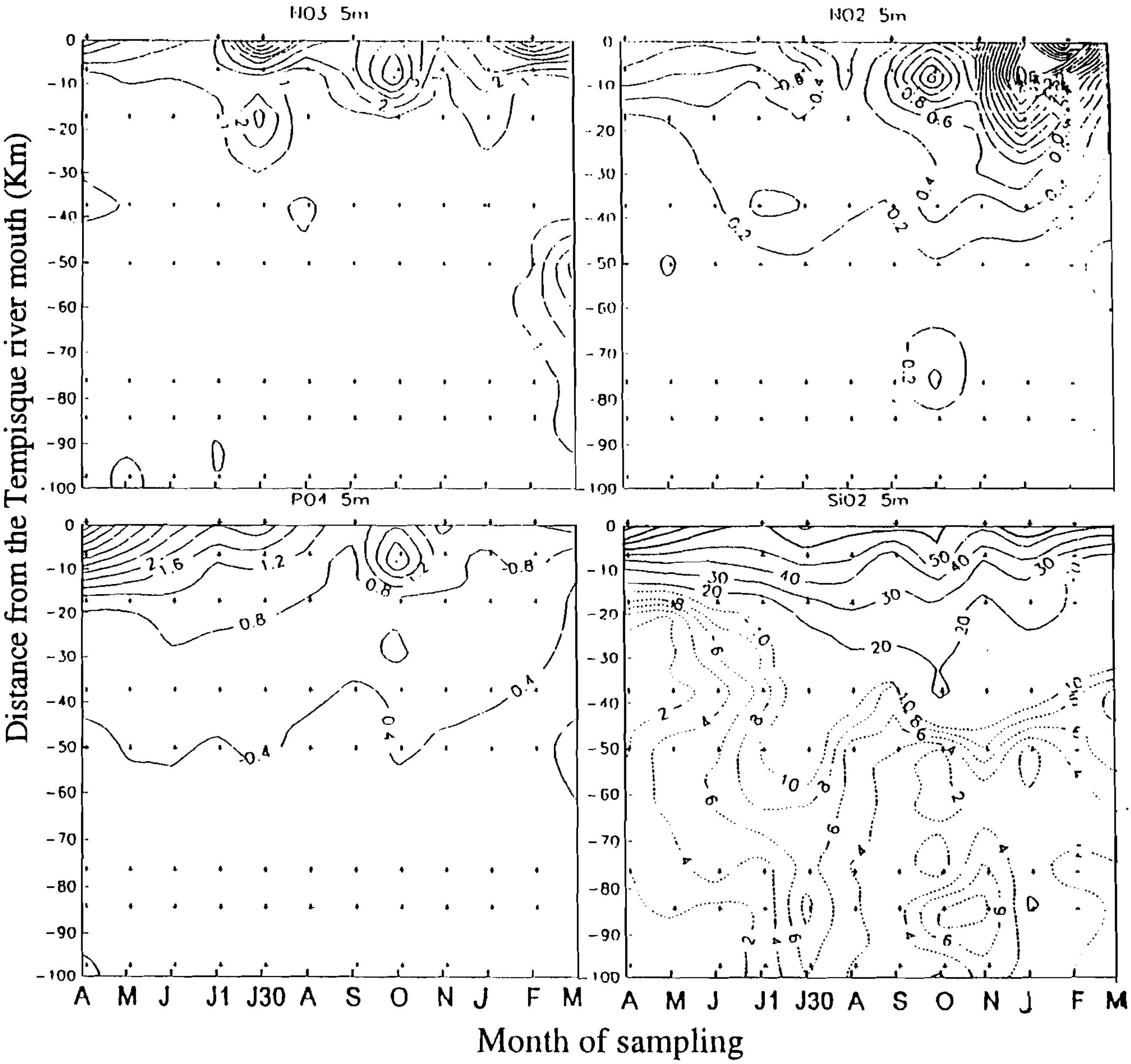


Figure 6. Nutrient concentration (μM) at 5 m depth, measured along the central transect of the Gulf, as a function of time of the year and distance from the Tempisque river mouth.

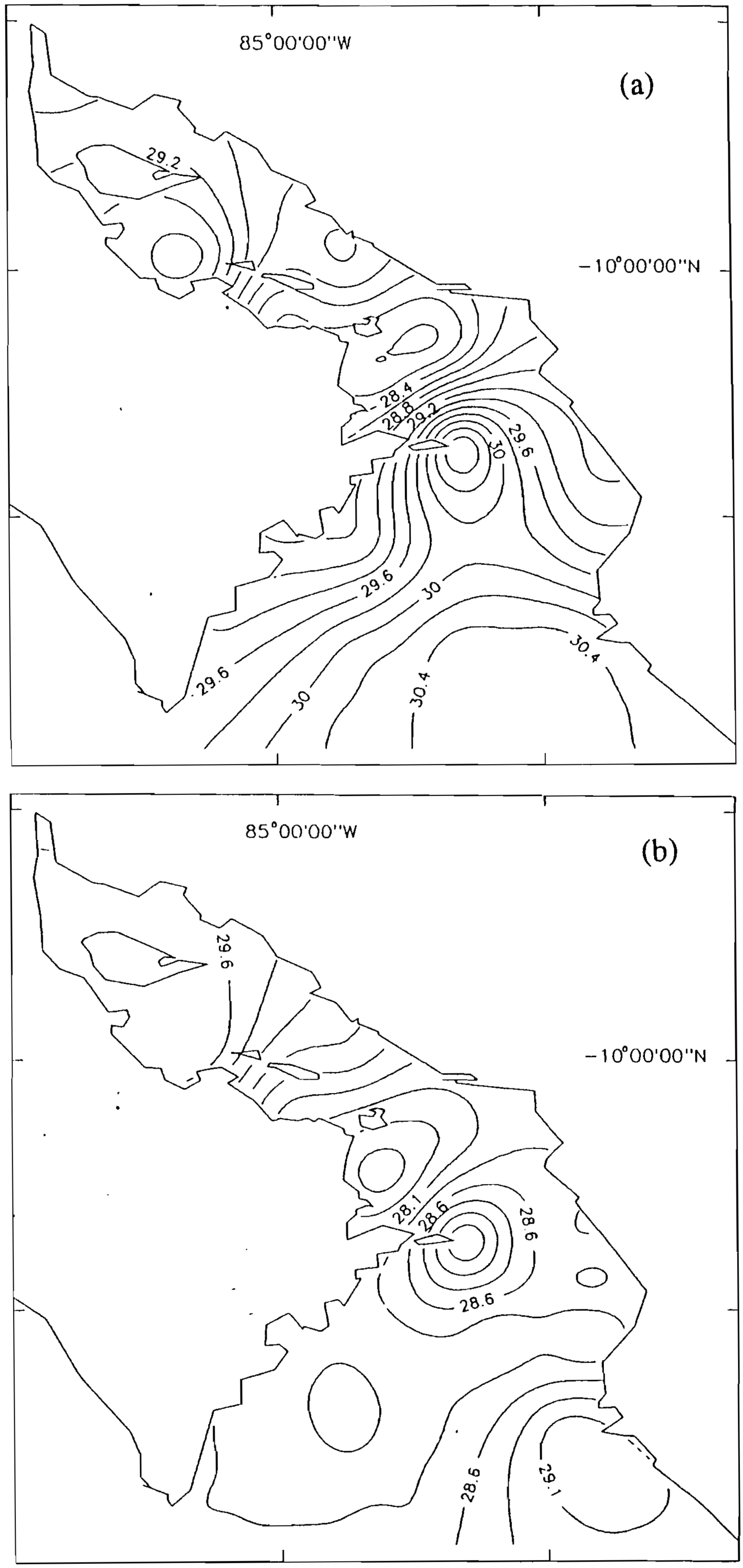


Figure 7. Spatial distribution of surficial temperature (^{0}C) during May 1992 (a) and October 1992 (b).

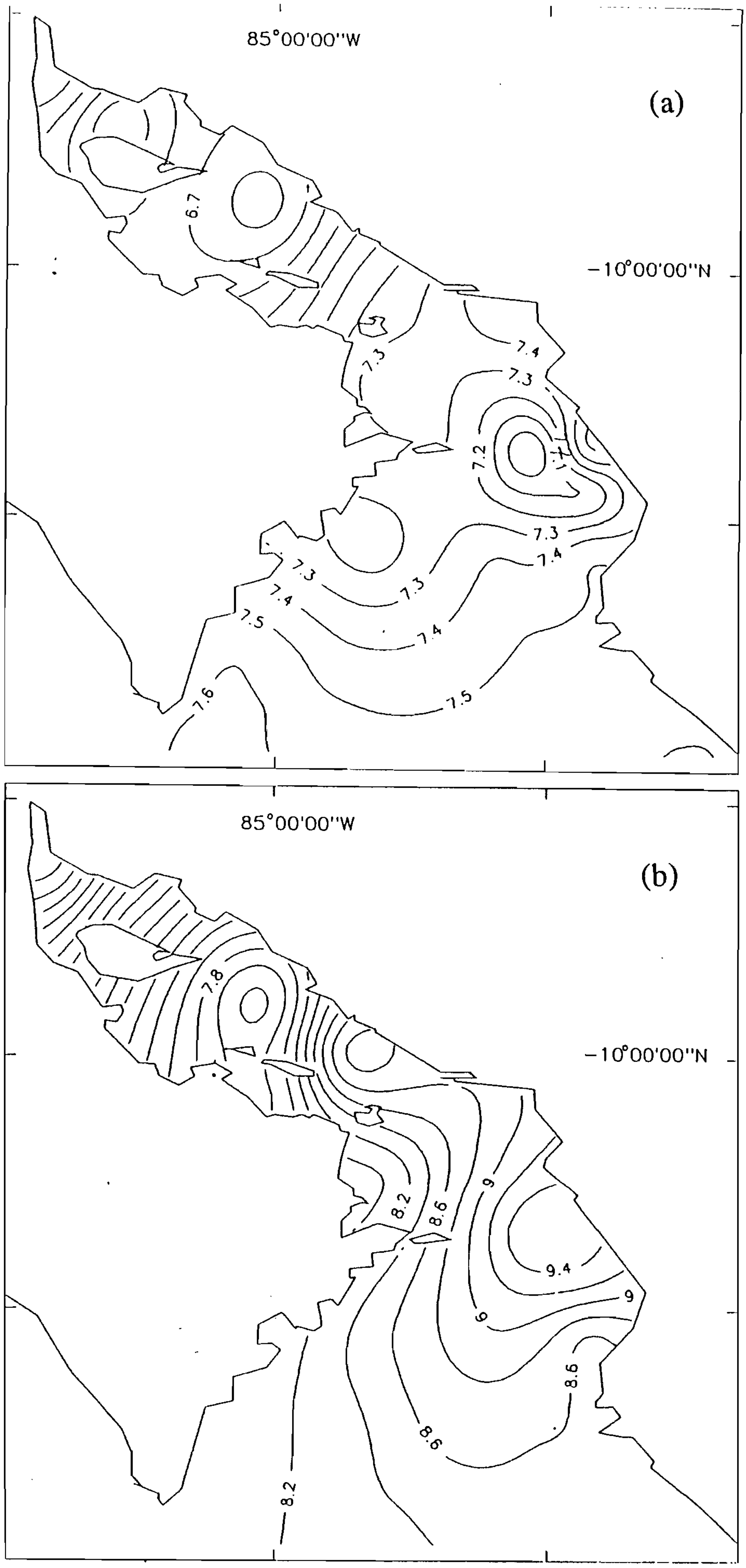


Figure 8. Spatial distribution of surficial dissolved oxygen concentration (ml/l) during February 1993 (a) and November 1992 (b).

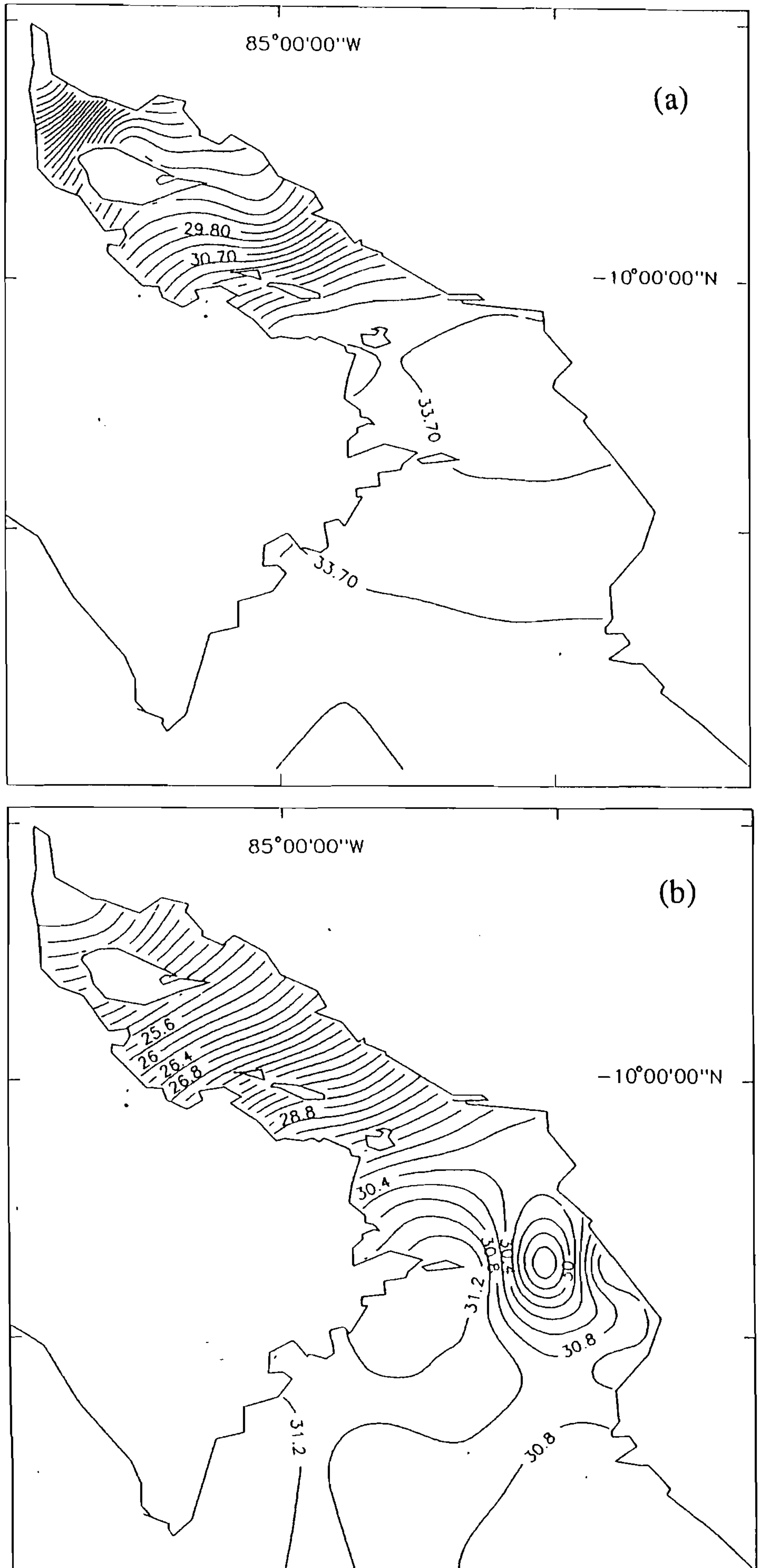
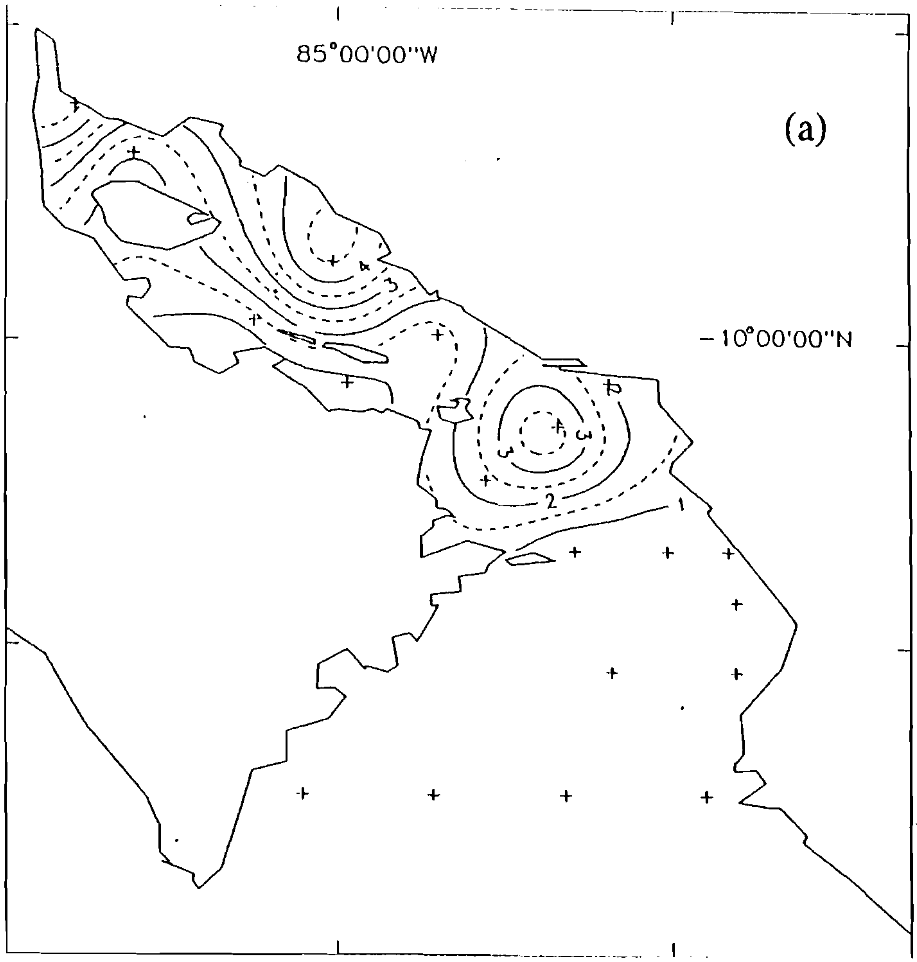


Figure 9. Spatial distribution of surficial salinity (ppt) during April 1992 (a) and October 1992 (b).



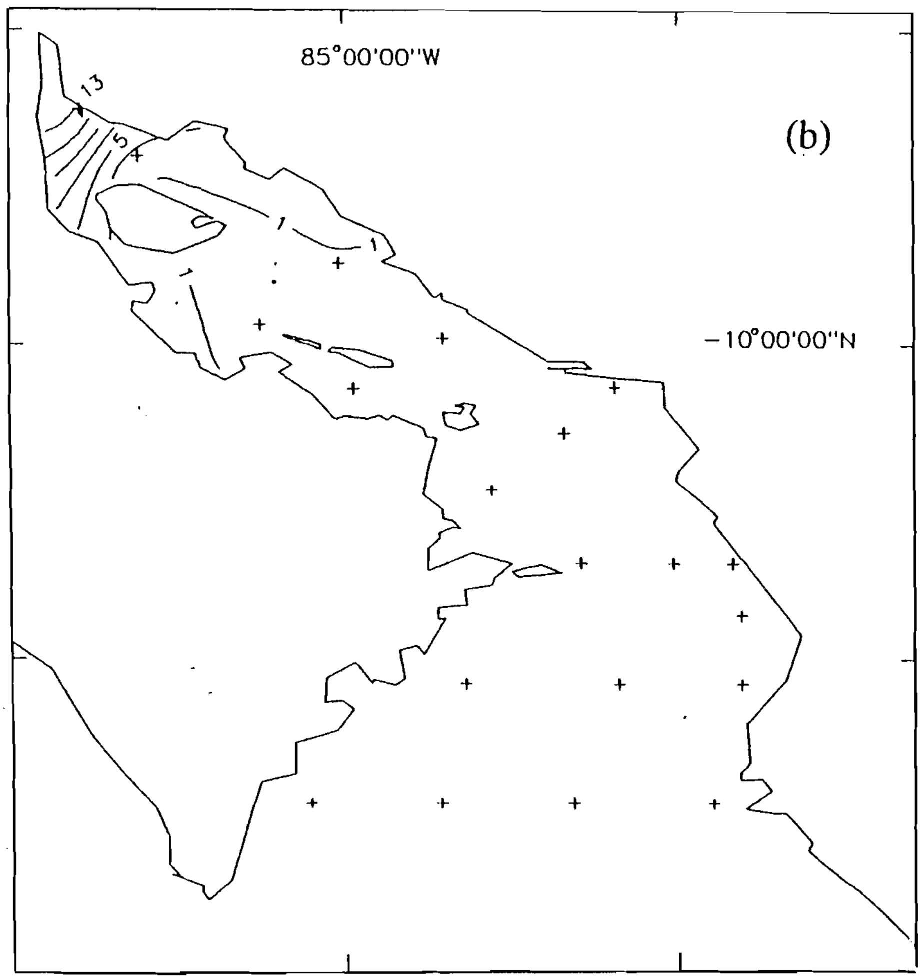


Figure 10. Spatial distribution of nitrate (μM) during March 1993 (a) and July 1992 (b).

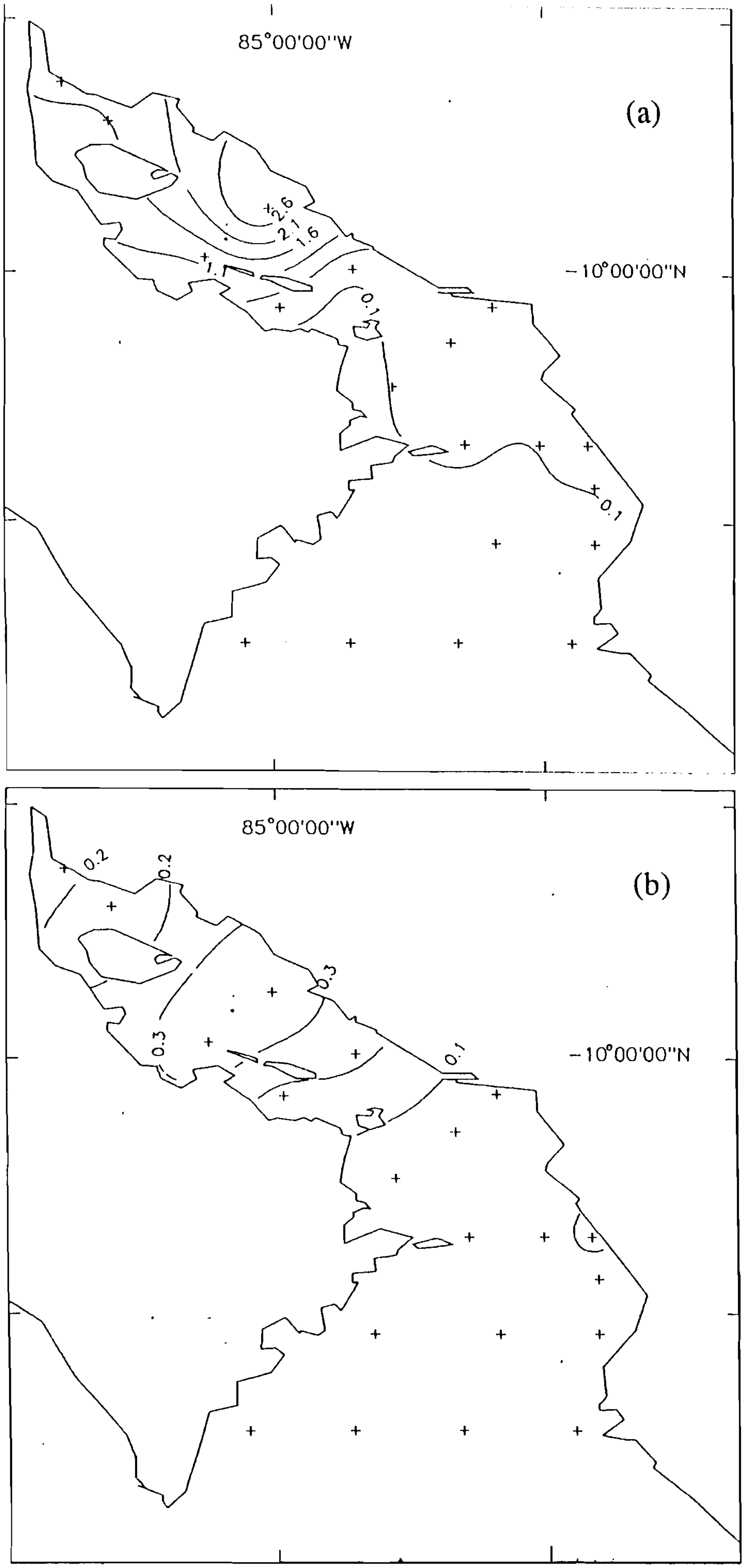
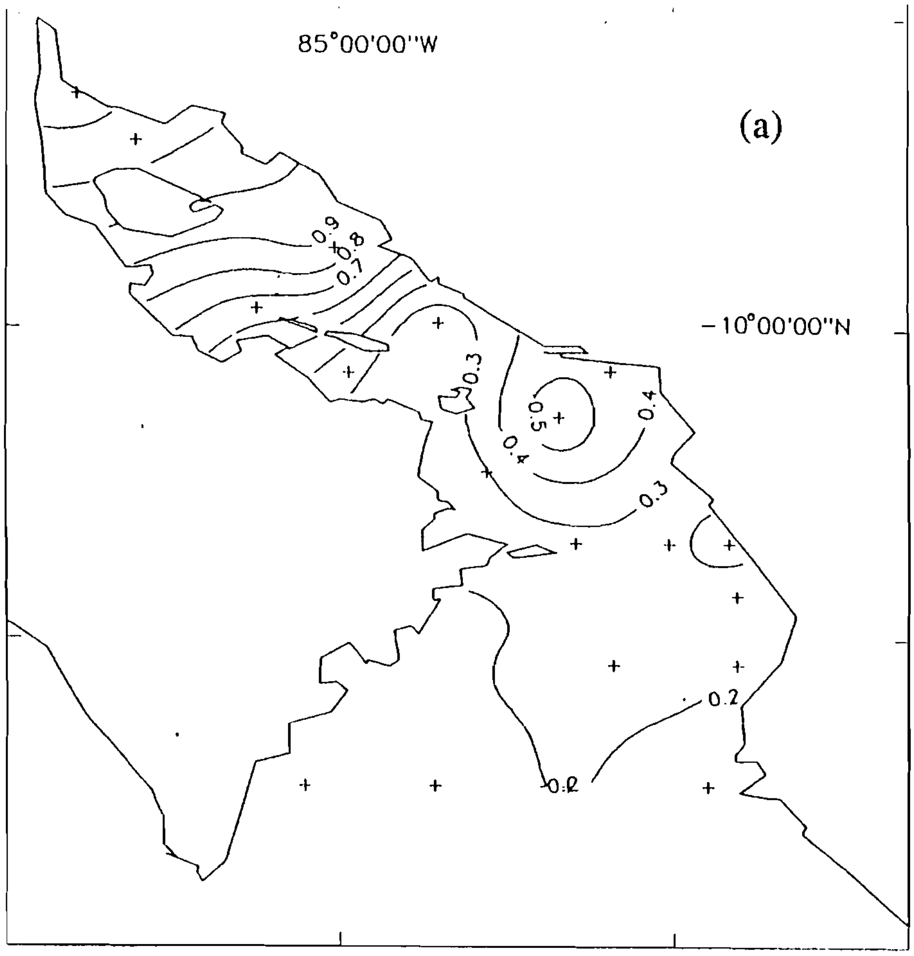


Figure 11. Spatial distribution of nitrite (μM) during March 1993 (a) and July 1992 (b).



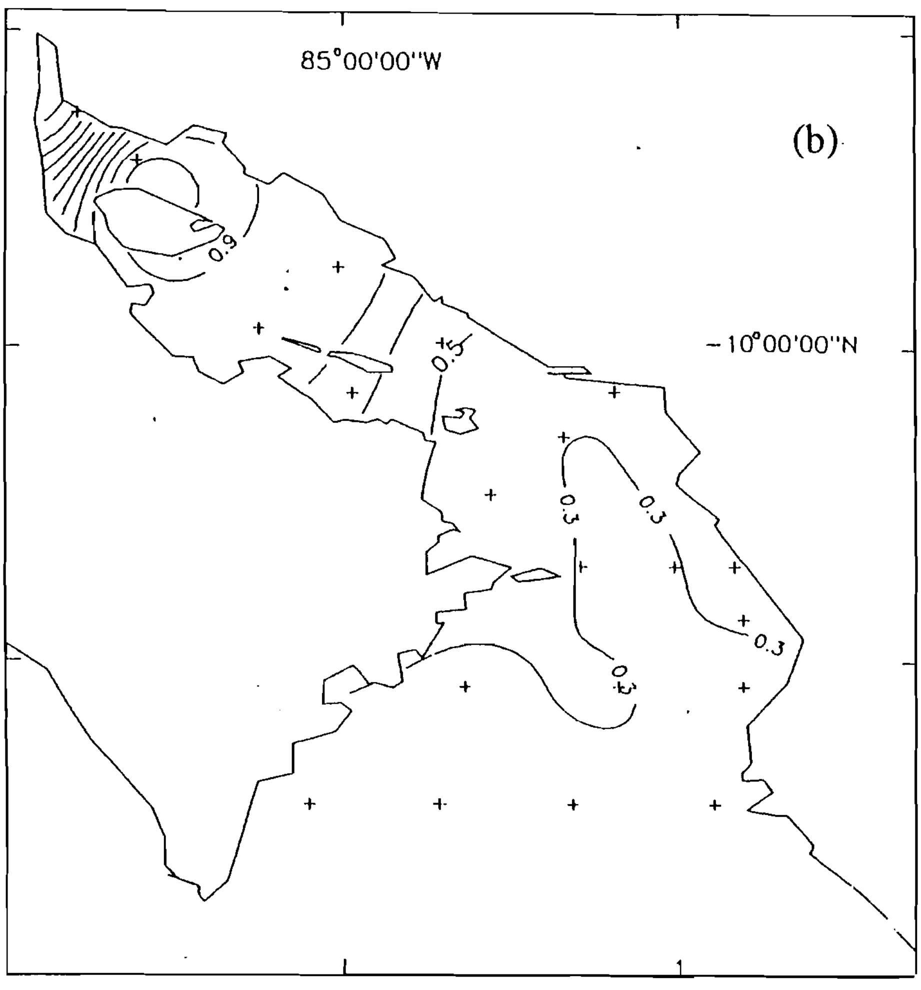


Figure 12. Spatial distribution of o-phosphate (μM) during March 1993(a) and July 1992 (b).

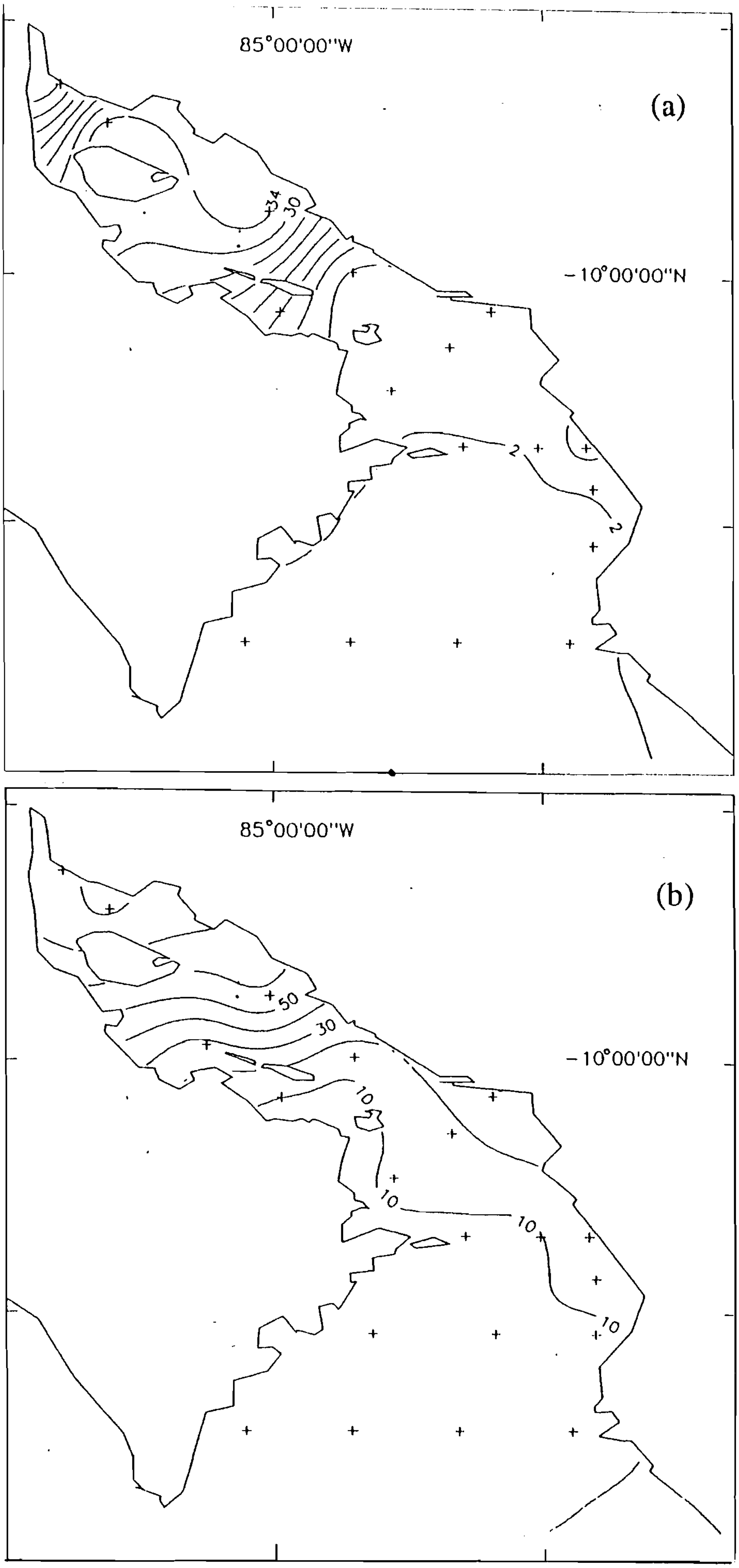


Figure 13. Spatial distribution of silicic acid (μM) during March 1993(a) and July 1992 (b).

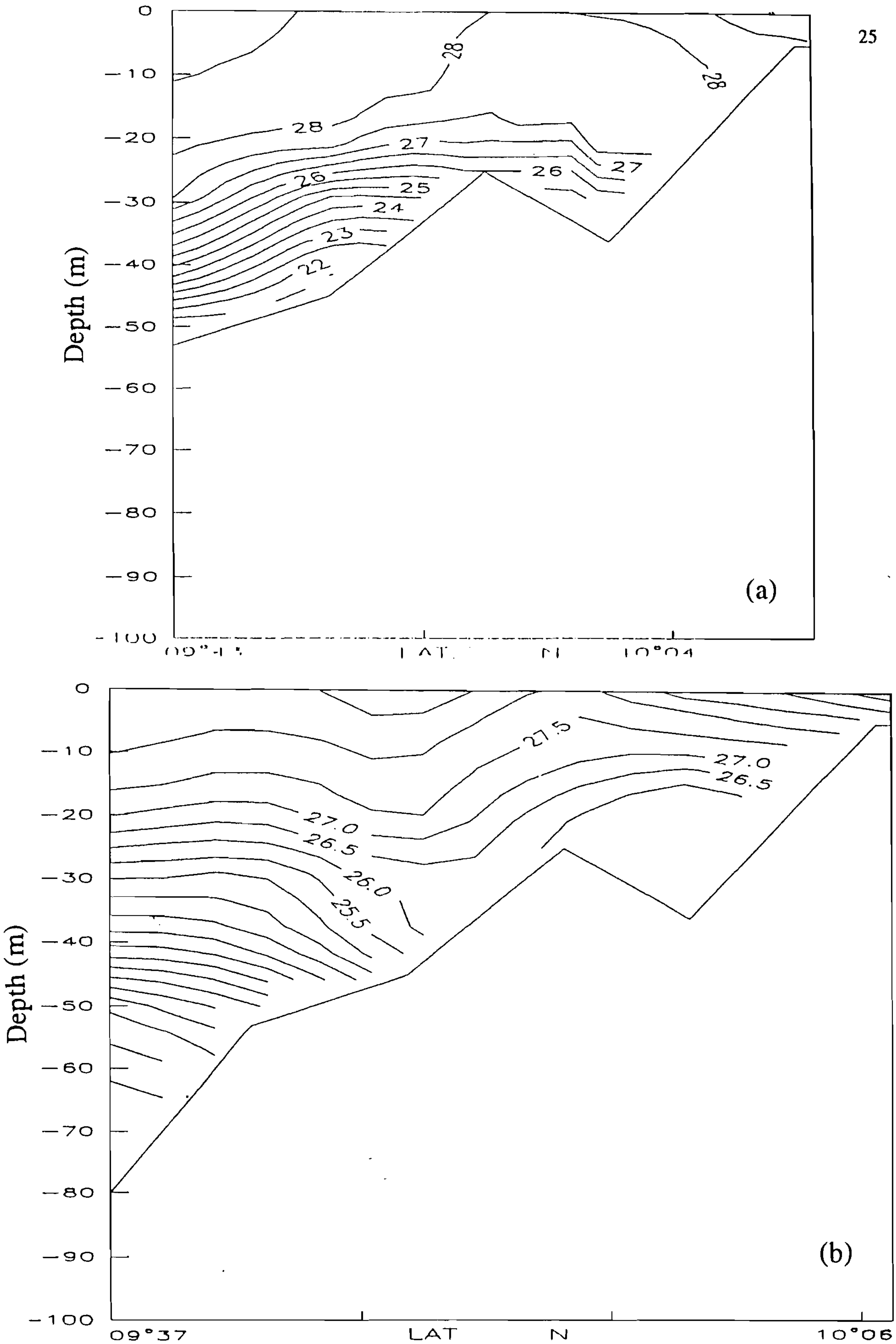


Figure 14. Temperature (^{0}C) depth profile along the central transect of the Gulf during February 1993 (a) and October 1992 (b).

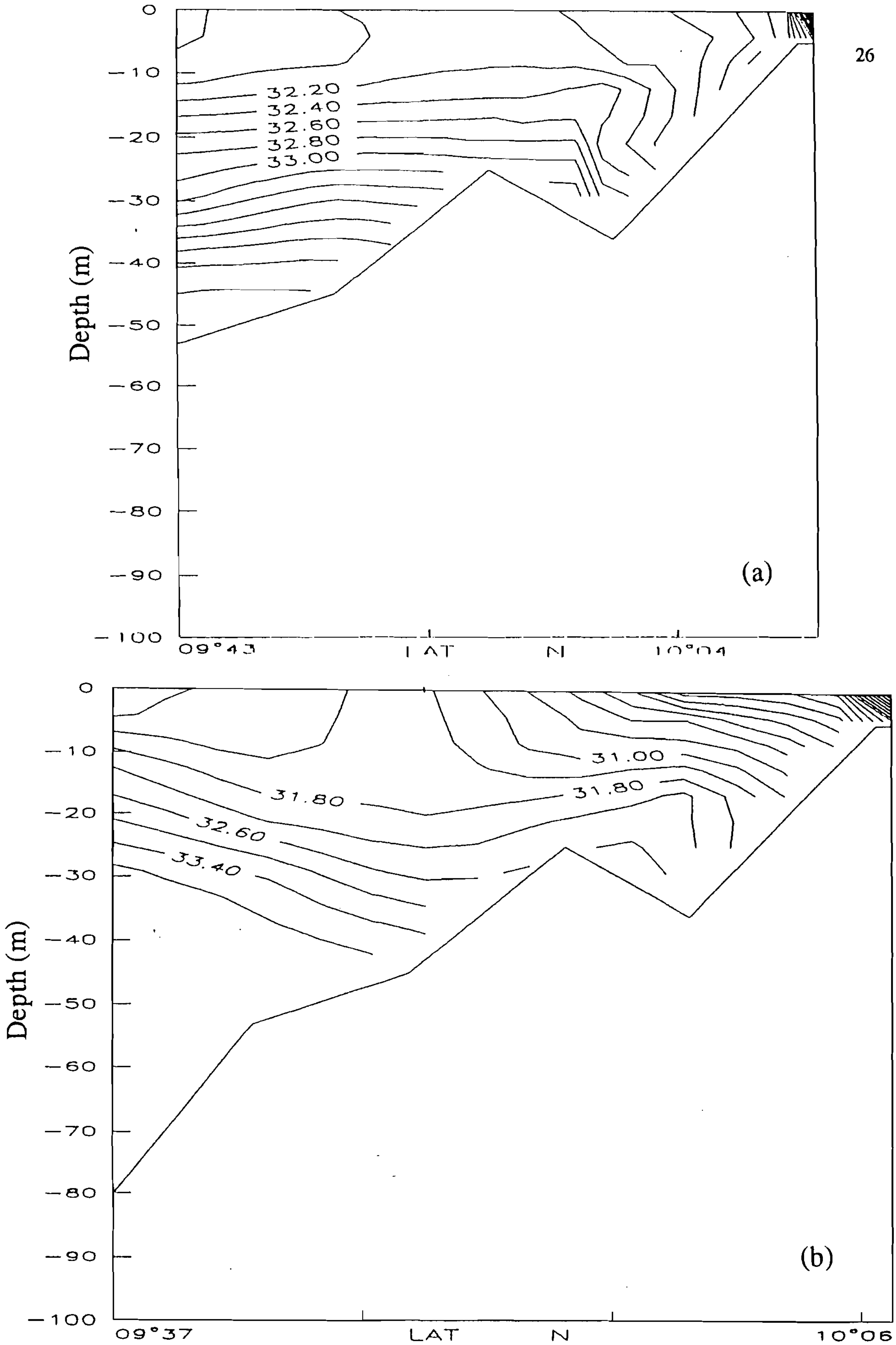


Figure 15. Salinity (ppt) depth profile along the central transect of the Gulf during February 1993(a) and October 1992 (b).

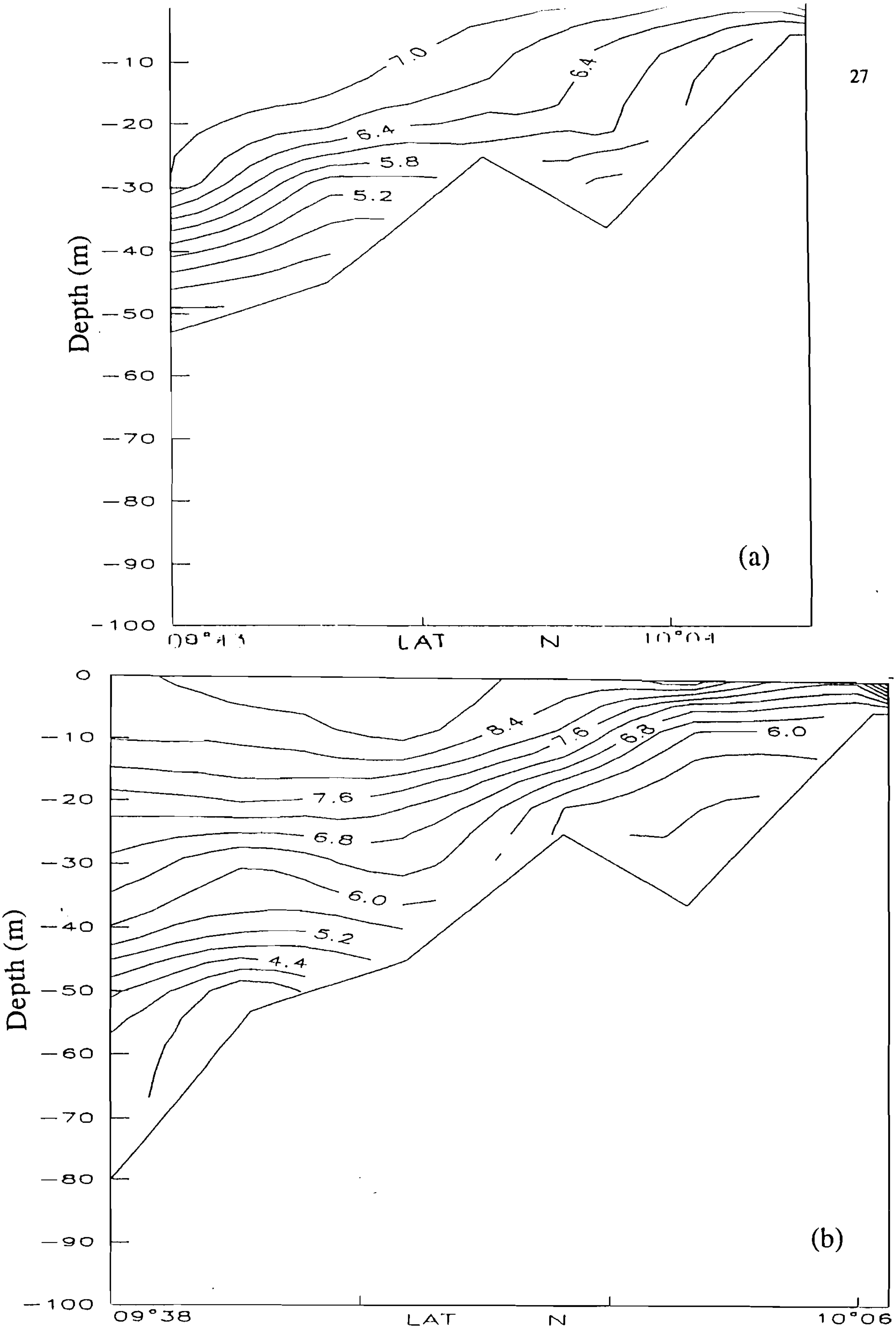


Figure 16. Dissolved oxygen (ml/l) depth profile along the central transect of the Gulf during February 1993 (a) and November 1992 (b).

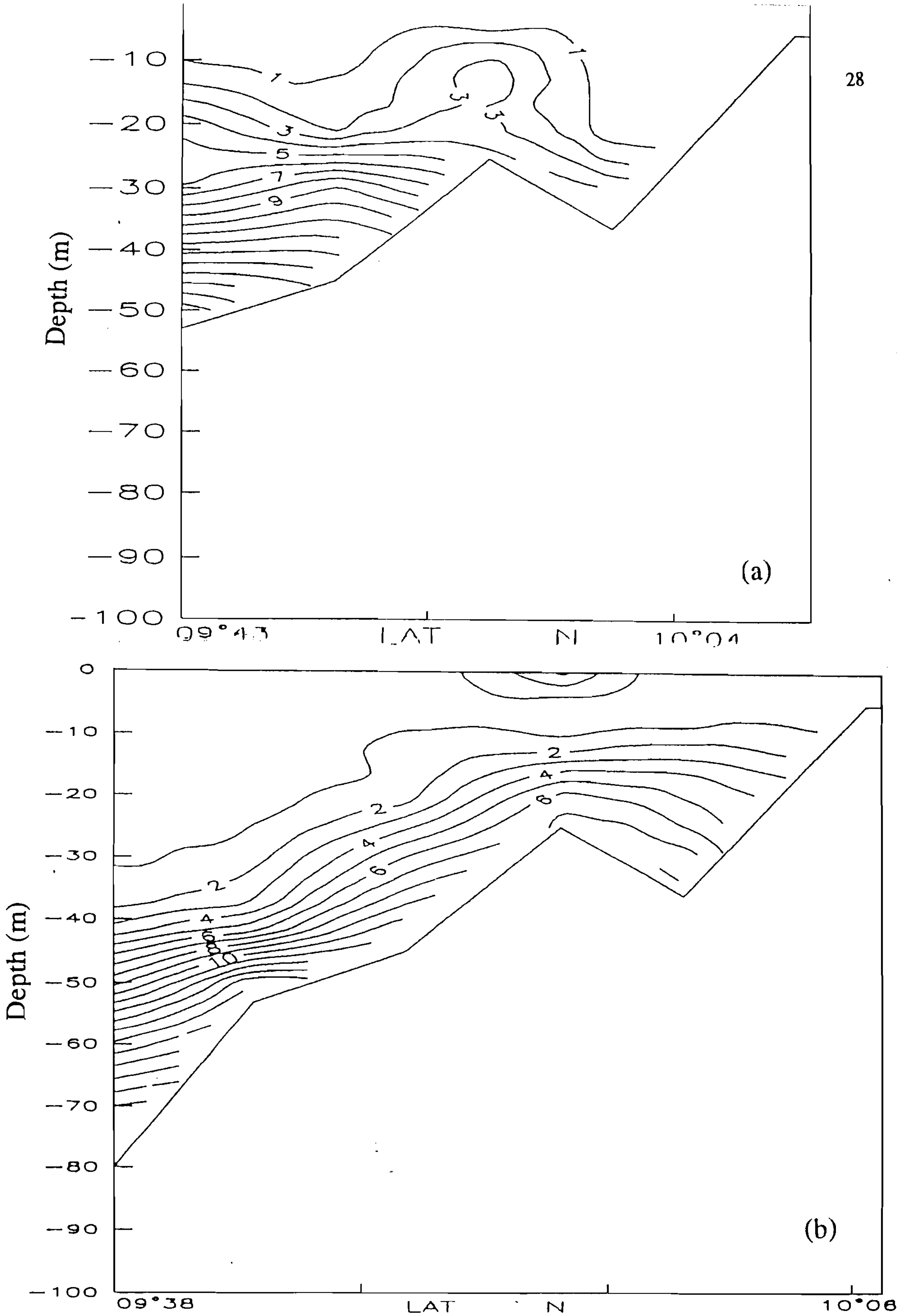


Figure 17. Nitrate (µM) depth profile along the central transect of the Gulf during February 1993(a) and November 1992 (b).

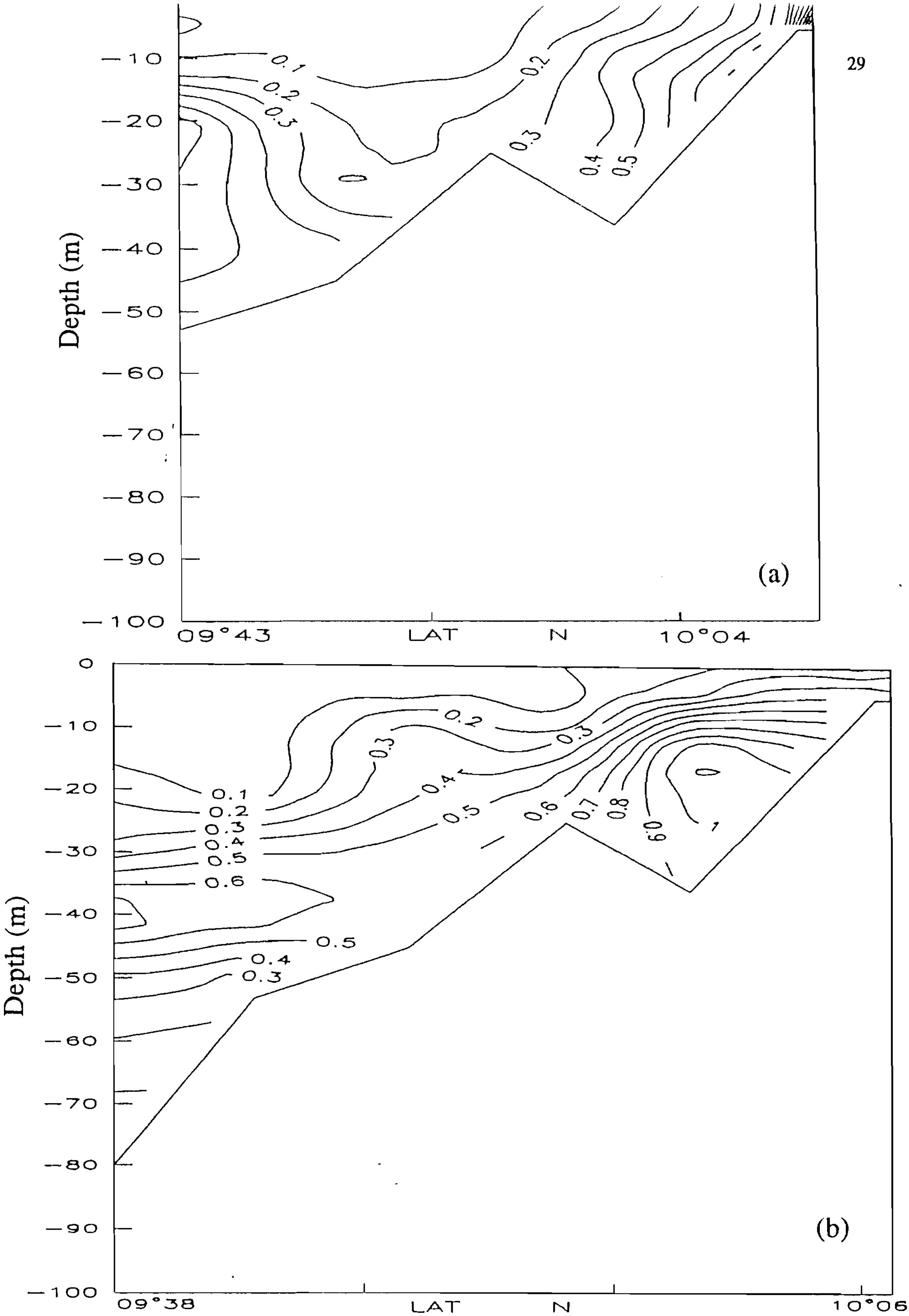


Figure 18. Nitrite (µM) depth profile along the central transect of the Gulf during February 1993(a) and November 1992 (b).

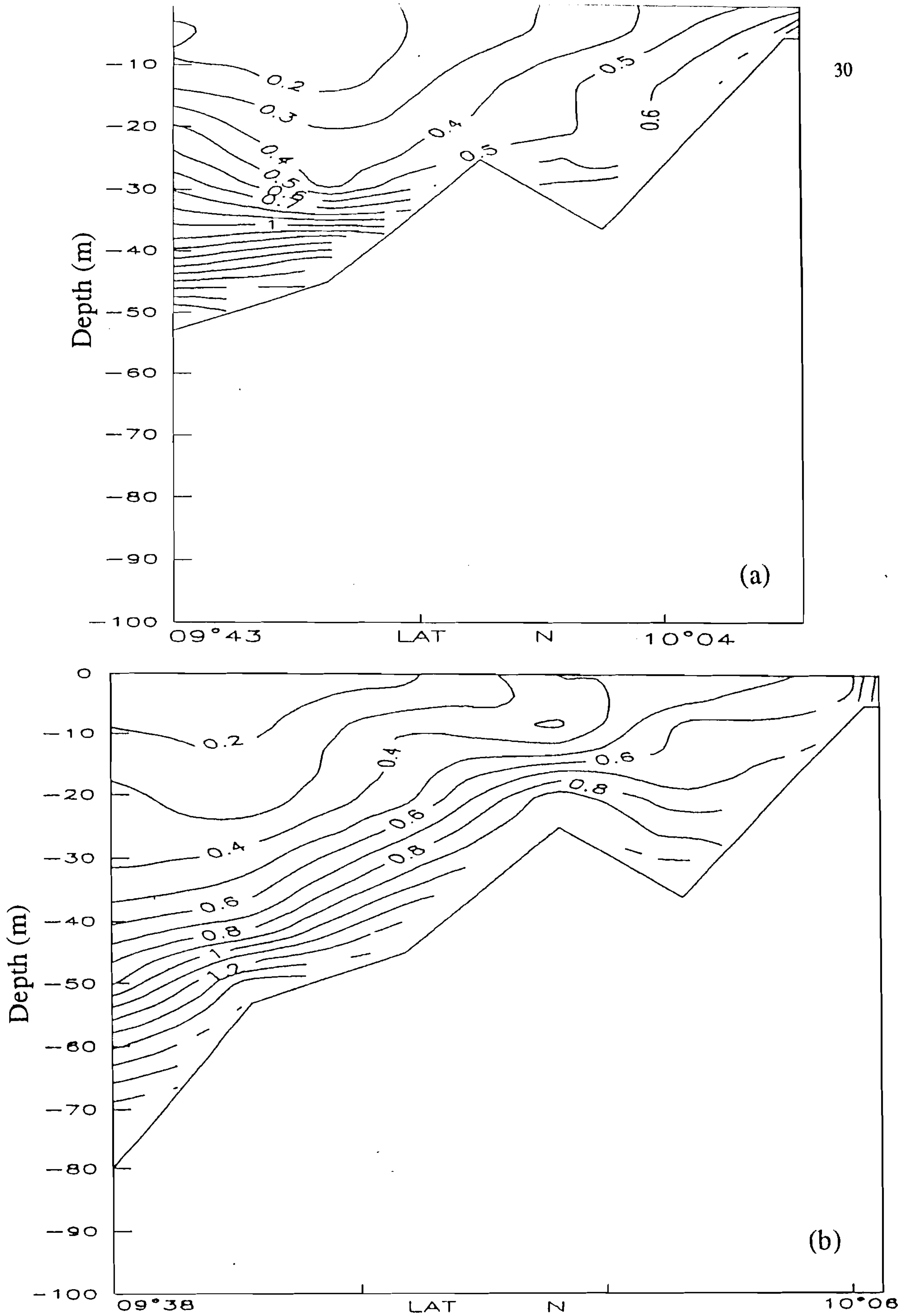


Figure 19. O-phosphate (μM) depth profile along the central transect of the Gulf during February 1993(a) and November 1992 (b).

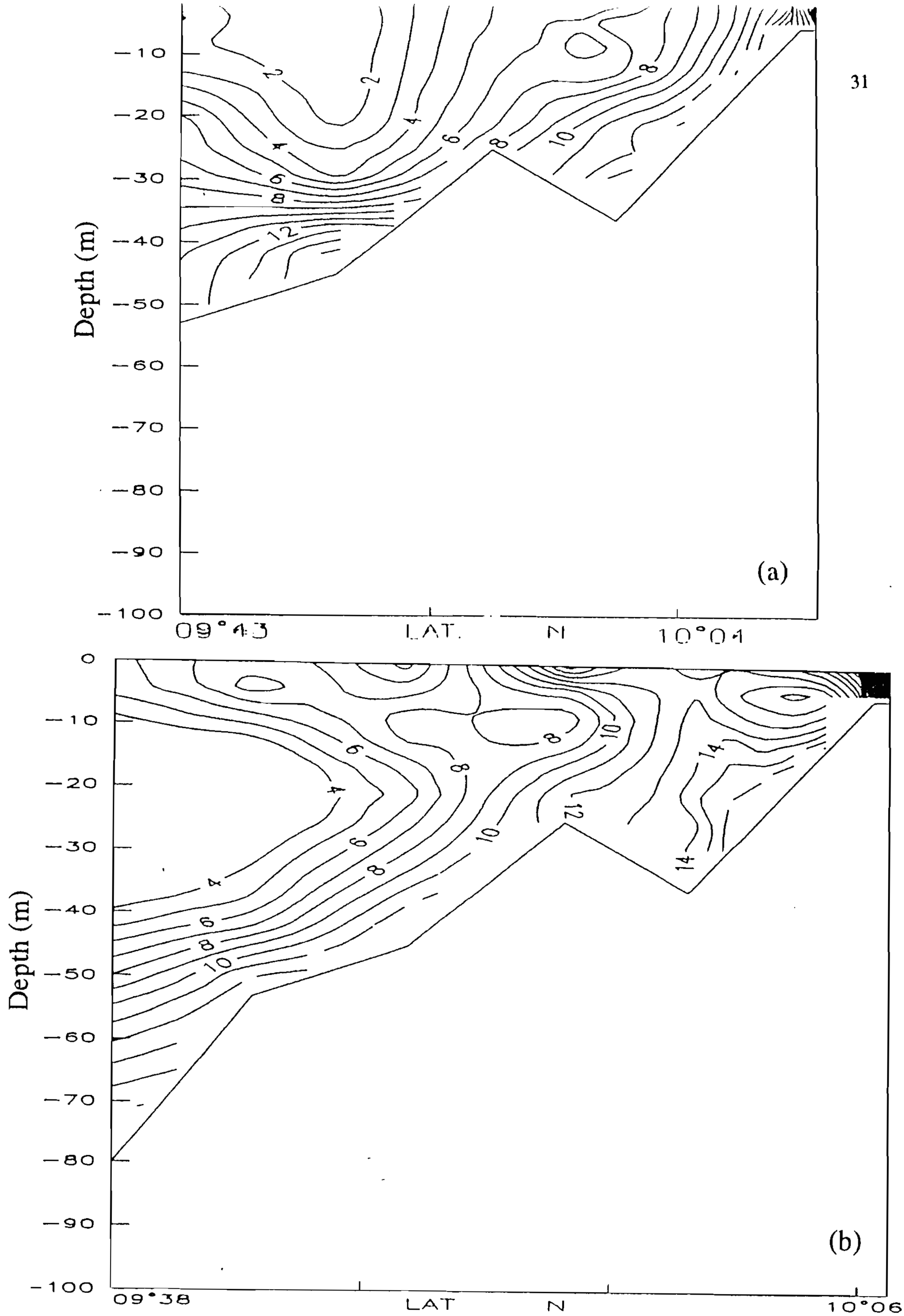


Figure 20. Silicic acid (µM) depth profile along the central transect of the Gulf during February 1993(a) and November 1992 (b).

B. Workplan for the second year of the project

1. Field work

Two cruises will be conducted in the Gulf during 1995, one at the dry season and one in the rainy season. 20 hydrographic stations will be occupied and profiles of temperature, salinity, dissolved oxygen, nutrients (o-phosphate, nitrate, nitrite and silicic acid) and chlorophyll - a determined. During these two cruises, sediments will also be sampled at the hydrographic stations and at three additional stations: one close to the Tempisque, one close to the Barrancas and one close to the Tarcoles river mouths.

Fish and benthic fauna will be collected at three different areas : the upper gulf, the Puntarenas-Tercoles region and a control area in the outer gulf, at the south-west bank. The samples will be analysed for their trace metal contents.

2.Visit of a Costa Rican scientist to Israel to study the methods used for heavy metals analysis.

The visit that was postponed from the first year of the project will take place between April and June 1995.

3. Hydrodynamic model

The hydrographycal model will be run and calibrated against existing data.
As the next step in adapting the POM to the Gulf, we will experiment with several model grids to establish the one best suited to the Gulf. The possibilities consist of a regular Cartesian grid or a curvilinear grid. The Cartesian grid uses a fixed grid spacing. It main advantage is that the numerical schemes are well behaved on this type of grid. The disadvantage is the many grid points are wasted over land. The curvilinear grid is set up to follow the coastlines as best as possible so that most of the grid points are concentrated in the Gulf. However, the sharp changes in the direction of the coastline (e.g. the transition from the lower to the upper Gulf) could lead to some numerical instabilities. A variety of experiments will be run to determine the final model grid.

Once the grid has been established, preliminary model runs will focus on the barotropic (two dimensional) tidally forced circulation. Once the model can properly simulate the tidal cycle in the Gulf we will then add the effects of wind forcing and possible surface heat fluxes. The final step will be to run fully three dimensional simulations. the number of vertical levels will be determined based in the available computer facilities.

4. Ecological model set-up

Set up and add new algorithms to the circulation model to describe the distribution of chemical-ecological parameters.